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Indian Standard

METHODS OF MEASUREMENT OF SUPPRESSION CHARACTERISTICS OF ELECTROMAGNETIC INTERFERENCE FILTERS

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Indian Standard
METHODS OF MEASUREMENT OF SUPPRESSION CHARACTERISTICS OF ELECTROMAGNETIC INTERFERENCE FILTERS

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Indian Standard

METHODS OF MEASUREMENT OF SUPPRESSION CHARACTERISTICS OF ELECTROMAGNETIC INTERFERENCE FILTERS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 28 August 1978, after the draft finalized by the Electromagnetic Interference Suppression Sectional Committee had been approved by Electronics and Telecommunication Division Council.

0.2 The object of this standard is to establish standard laboratory method of measurement of insertion loss of passive electromagnetic interference filters which may consist of single elements such as capacitors, inductors or resistors, or combination of inductors, capacitors and resistors of either the bumped or distributed types.

0.3 As a general rule, suppression characteristics of electromagnetic interference filter depend on impedances between which the filters work (because they are of decisive importance for energy reflection on the input of the filter), on operating current and voltage levels and also on other factors such as ambient temperature.

0.4 In order to make it possible to compare the results of measurements of suppression characteristics performed in various laboratories, or reported by various manufacturers, standard test methods shall be used.

0.5 While preparing the standard, assistance has been derived from CISPR/A (Secretariat) 13 Second draft of report — Methods of measurement of the suppression characteristics of passive radio interference suppression devices and radio interference filters, issued by International Special Committee on Radio Interference (CISPR).

0.6 The limits for electromagnetic interference are covered by IS: 6842-1977*.

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS:2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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*Specification for limits for electromagnetic interference (*first revision*).

†Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard prescribes methods of measurement of insertion loss of passive electromagnetic interference suppression filters which may consist of single elements, such as capacitors, inductors or resistors, or combination of inductors, capacitors and resistors of either the bumped or distributed types.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions in addition to those given in IS: 1885 (Part XXXVI)-1972*, shall apply.

2.1 Insertion Loss — At a given frequency, the insertion loss of a filter connected into a given transmission system is defined as the ratio of voltage appearing across the line immediately beyond the point of insertion, before and after insertion of the filter under test. As specified herein, the insertion loss is measured in the specified system with fixed, real and equal impedances of the equivalent generator and receiver.

2.2 Load Current — DC or ac mains frequency current flowing through the current conductor(s) of the filter under test.

2.3 Load Voltage — DC or ac mains frequency voltage applied between specified parts of the filter under test.

2.4 Impedance of the Test Circuit — Impedance across the terminals of the test circuit without the filter connected.

2.5 Asymmetrical Test Circuit — A test circuit in which the filter under test is connected with coaxial cable of which the outer conductor constitutes a return path for high frequency current.

2.6 Symmetrical Test Circuit — A test circuit in which the filter under test is connected with screened conductor pairs and in which asymmetric voltage is small enough to be neglected.

2.7 Symmetry Coefficient of Symmetrical Test Circuit — The ratio of symmetrical and asymmetrical voltages which appear at the point of connecting the filter under test (expressed in dB).

3. STANDARD LABORATORY METHODS (*see* Appendix A)

3.1 The measurement of suppression characteristics of the filter is made with it terminated in fixed resistance normally 50 to 75 ohms (insertion loss measurement). Two variants are in use, namely:

a) filter without load, and
b) filter under full dc or ac load (current and/or voltage).

NOTE — The characteristics obtained may differ from that one observed in practice because the terminating impedances during the measurement differ from those existing during its use in an actual device.

*Electrotechnical vocabulary: Part XXXVI Radio interference.

4. FILTER MOUNTING ARRANGEMENTS

4.0 The filter under test shall be mounted in an appropriate test container. Unless the specific test arrangement is otherwise specified by the manufacturer, the test container shall be as described in **4.1**.

4.1 Construction of the Container — The interference suppression elements and filters which have no screens and coaxial plugs of their own at the input and output are placed for measurements into a test container whose dimensions depend on those of the article under test, for example on its length l, height h and width w. A container is a box which is supplied with a lid and is made of non-magnetic metal. A container which is intended for measurement of feed through capacitors and filters with flange mounting should have an internal partition with a hole for mounting of capacitors and filters. Reliable electrical contact should exist between separate parts of the container. Separate parts of the housing are joined by soldering or continuous seam welding; the lid and the housing are joined together by a spring contact device or by a screw joint.

4.1.1 Coaxial jacks should be mounted on two walls of the container.

4.2 Mounting of the Interference Suppression Filters in the Containers

4.2.1 *Capacitors and Filters*

4.2.1.1 *Non-feedthrough types* — Capacitors with two flexible leads are mounted according to Fig. 1A, capacitors with two insulated rigid leads according to Fig. 1B, capacitors with one insulated rigid lead, according to Fig. 1C, and capacitors and four-terminal non-coaxial filters according to Fig. 1D.

4.2.1.2 *Feedthrough types* — The mounting and connecting of capacitors of feedthrough type and of filters with flange mounting should be as shown in Fig. 2A. The mounting and connecting of filters and feedthrough capacitor fixed by clamps should be as shown in Fig. 2B. The mounting and connecting of filters with screened leads should be as shown in Fig. 2C. Where filters are designed to be part of an integral coaxial structure, the mounting shall be as shown in Fig. 2D.

4.2.2 *Chokes* — The mounting and connecting of large-sized chokes should be shown in Fig. 3A and of small-sized chokes (with a diameter up to 10 mm) as shown in Fig. 3B.

4.2.3 *Interference Suppression Resistors, Cables and Other Filters Used for Suppression of Interference from Ignition Systems of Vehicles*

4.2.3.1 The mounting for connecting and making of measurements should comply with the requirements of **5.1** of IS: 6873 (Part I)-1977*.

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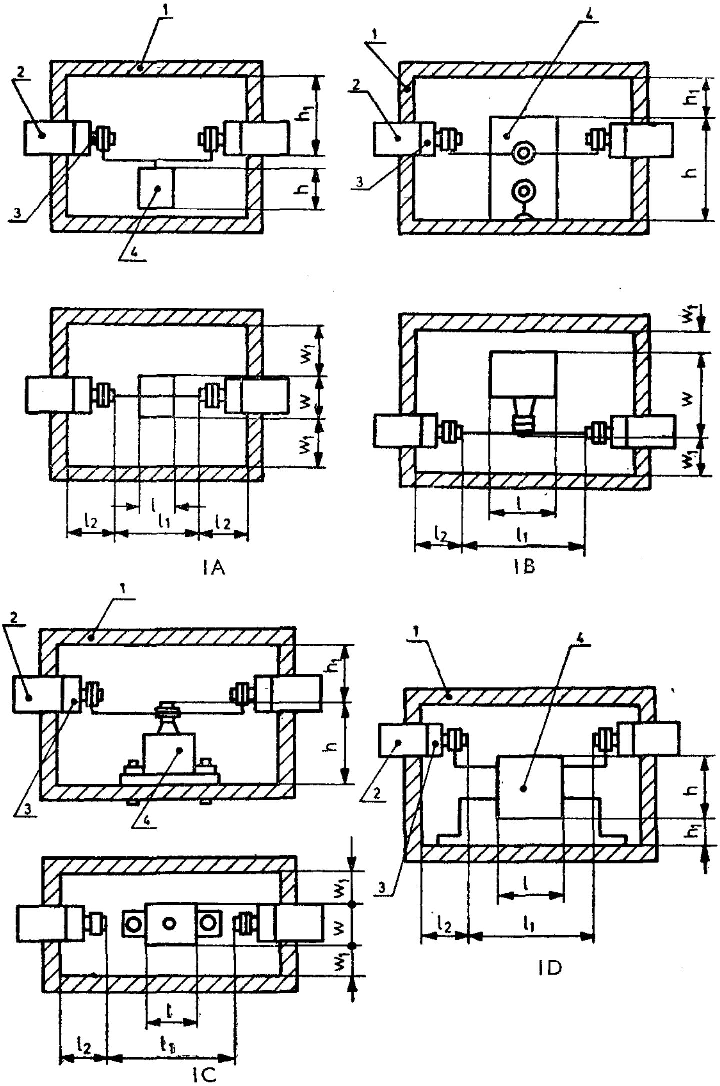
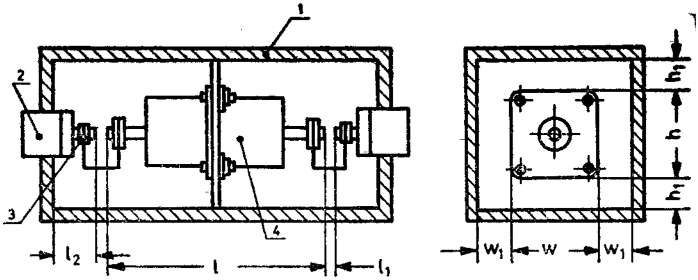
*Methods of measurement of electromagnetic interference: Part I From ignition systems o f motor vehicles and other similiar devices (*first revision*).



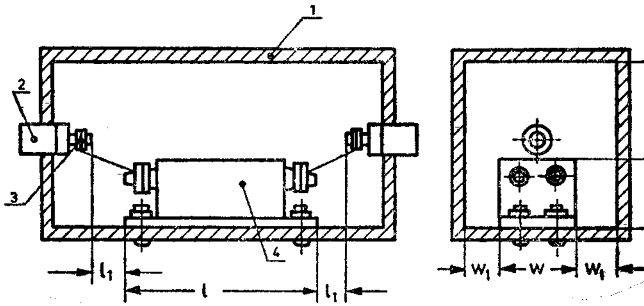
1. Container
2. Coaxial plug
3. Element of the mounting
4. Object under test

l_1 should be not greater than $l+20$ mm, l_2 not greater than 20 mm, h_1 and w_1 not greater than 80 mm.

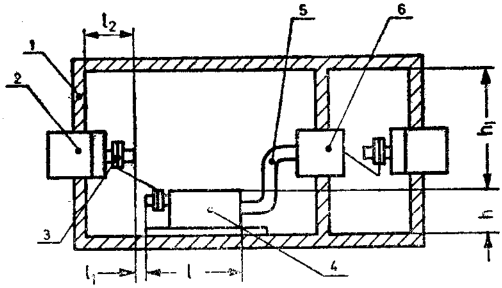
FIG. 1 MOUNTING OF NON-FEEDTHROUGH TYPE CAPACITORS



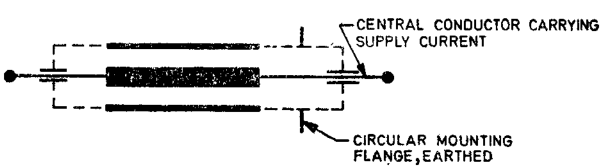
2A



2B



2C

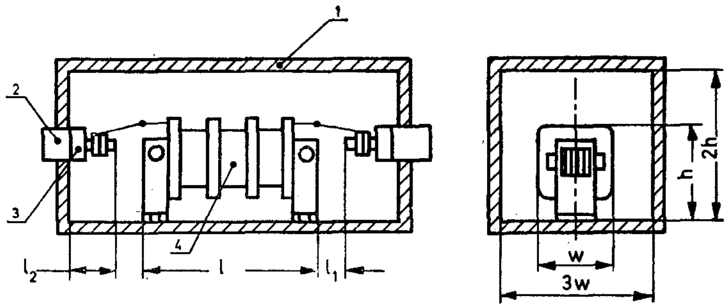


2D

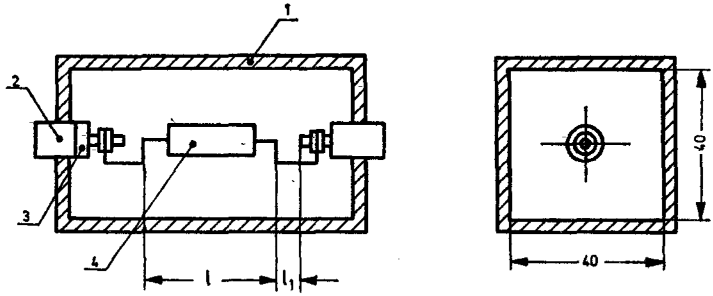
1. Container	2. Coaxial plug	3. Element of the mounting
4. Object under test	5. Screened lead	6. Screened plug

l_1 should be not greater than 10 mm, l_2 not greater than 20 mm, h_1 and w_1 not greater than 40 mm.

FIG. 2 MOUNTING OF FEEDTHROUGH TYPE CAPACITORS



3A



3B

1. Container
2. Coaxial plug
3. Element of the mounting
4. Object under test

l_1 should be not greater than 10 mm, l_2 not greater than 20 mm.

FIG. 3 MOUNTING OF CHOKES

APPENDIX A

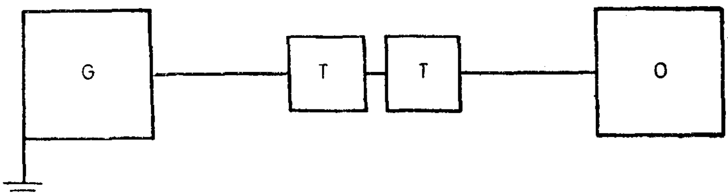
(Clause 3)

STANDARD LABORATORY METHODS OF INSERTION LOSS MEASUREMENT OF SUPPRESSION FILTERS

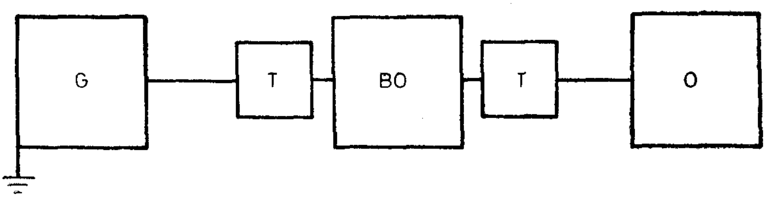
A-1. REQUIREMENTS

A-1.1 Basic Test Circuit — The basic test circuit shall be arranged as shown in Fig. 4 and 5. All elements of the circuit shall be screened. An asymmetrical (coaxial) test circuit shall be used for measurement of filters intended for asymmetrical interference voltage suppression and a symmetrical test circuit shall be used for measurement of filters intended for a symmetrical interference voltage suppression.

NOTE — Practical modifications of test circuits shown in Fig. 4 and 5 are given in **A-3**.



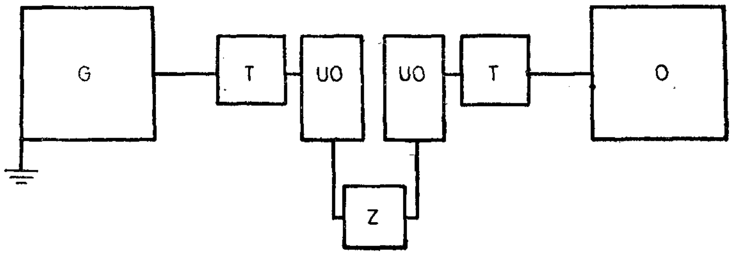
4A Reference Circuit



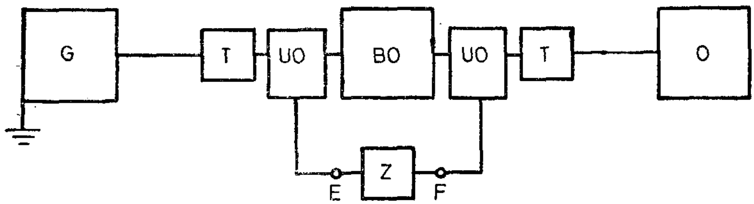
4B Measurement Circuit

BO = Filter under test
G = Generator
T = Isolation attenuator 10 dB
O = Receiver

FIG. 4 BASIC TEST CIRCUIT FOR MEASUREMENT WITHOUT LOAD



5A Reference Circuit



5B Measurement Circuit

BO = Filter under test
T = Isolation attenuator 10 dB
UO = Buffer-network
O = Receiver
Z = Current or voltage source, terminals *E* and *F* are not connected to ground
G = Generator

FIG. 5 BASIC TEST CIRCUIT FOR MEASUREMENT WITH LEAD APPLIED

A-1.2 Principal Characteristics of the Test Circuit — The principal characteristics of the test circuit shall be within the limits given below:

Characteristics of the Test Circuit	*Value*
Impedance	50 or 75 ohms
VSWR	1·2, *Max*
Symmetry coefficient (only for symmetrical test circuits)	26 dB, *Min*
Accuracy:	
Max measurable insertion loss	10 dB better than required level [*see* **A-1.7**(d)]
a) Insertion loss	±3 dB
b) For levels over 80 dB	±6 dB
c) Frequency	±2·0 percent

NOTE — Characteristics shall be maintained on each measuring frequency and for each value of load current and voltage.

A-1.3 Test Equipment

A-1.3.1 *Signal Generator* — A sinusoidal signal generator is recommended. Generators of other signals (for example noise or impulse), which have a uniform output spectrum in the frequency range of interest, may be used but in such cases the receiver shall have good selectivity and spurious rejection.

A-1.3.2 *Receiver* — A selective receiver (having at least one resonant circuit before the first amplifying stage) is recommended. The use of a nonselective receiver is acceptable if harmonic and other undesirable frequencies in the output of the generator are small enough so as not to affect the results of measurement.

A-1.3.3 *Load Current or Voltage Source* — The source providing loading current or voltage shall be floating and have both terminals (E and F in Fig. 5) isolated from ground with the possibility of grounding any of them when it is appropriate.

NOTE 1 — Substantial simplification of the measurement procedure can be achieved when using a suitable sweep generator and panoramic receiver tuned synchronously. The suppression characteristic may then be observed on an oscilloscope screen or automatically recorded.

NOTE 2 — Examples of buffer-networks are given in Appendix B.

A-1.4 Method of Test — Measurements shall be performed in two steps. In the first step the test circuit shall be arranged without the filter under test and the generator and the receiver shall be directly connected *via* suitable cable. The generator shall be adjusted to the desired frequency and the receiver tuned to resonance at the frequency of the generator. The output voltage of the generator and input voltage of the receiver shall be recorded.

In the second step the test circuit shall be arranged in filter-in condition and voltages once more shall be recorded.

The insertion loss of the filter under test can be found from the formula:

$$A = 20 \log_{10} \frac{U_{01}}{U_{02}} + 20 \log_{10} \frac{E_{g2}}{E_{g1}} + A_{tr}$$

where

U_{01} = input voltage of the receiver in filter-out condition,

U_{02} = input voltage of the receiver in filter-in condition,

E_{g1} = emf of the generator in filter-out condition,

E_{g2} = emf of the generator in filter-in condition,

A_{tr} = value of attenuation (in dB) for a calibrated attenuator which replaces the filter under test in an approximate circuit (*see* **A-3**).

NOTE — In practice it is convenient to deal with readings from the generator (or receiver) only and for this purpose the second voltage is maintained at the constant level $U_{01} = U_{02}$ (or $E_{g1} = E_{g2}$); for more details, *see* **A-3**.

A-1.5 Connection of the Filter Under Test

A-1.5.1 The connection of the filter under test and especially the length and positioning of its connecting leads shall correspond to manufacturer's instructions for use, if any.

A-1.5.2 Filters for suppression of symmetrical and asymmetrical voltage shall be tested respectively in symmetrical and asymmetrical test circuits.

NOTE — In the symmetrical test circuits, the symmetrical generators and receivers used in conjunction with proper unbalance to balance transformers.

A-1.5.3 Multiple independent circuit filters shall be tested for each lead separately Z_0 shall be placed on all unused terminations and shall be consistent with the Z_0 of the line, generator and receiver. Additionally, coupling between individual leads shall be tested with the leads loaded with Z_0 as shown in the Fig. 6.

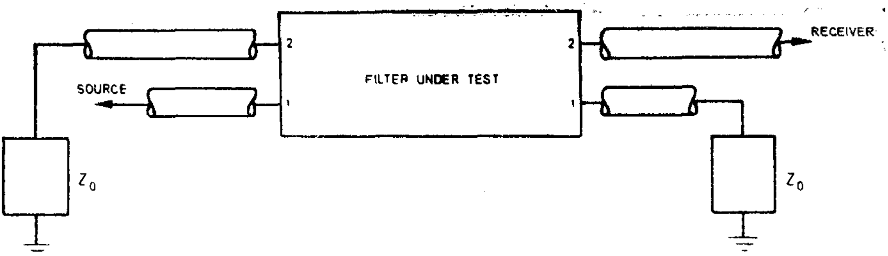


FIG. 6 ARRANGEMENT TO TEST FILTER

A-1.6 Mounting of the Filter in the Test Circuit — Mounting of the filter in the test circuit shall correspond to that in normal use and as specified by the manufacturer. The arrangement shall not disturb continuity and effectiveness of test-circuit screening. Unless specified otherwise, the filter under test shall be played in a test-box as specified in **4**.

A-1.7 Presentation of the Results— The report of measurements shall contain the following specific data:

a) Test circuit impedance;

b) Results of measurements for example in the form of a table or diagram drawing the insertion loss in dB as a function of frequency in orthogonal semi-logarithmic coordinates;

c) Description (sketch) of connectors and mounting of the filter in the test circuit containing the shape and dimensions of the test-box and connecting leads (if needed);

d) Maximum measurable insertion loss of test circuit (only if it is less than 10 dB greater than actually measured values for filter under test).

A-2. METHODS OF VERIFICATION OF TEST CIRCUIT MAIN PARAMETERS

A-2.1 VSWR Checking

A-2.1.1 *Method I* — The test circuit shall be divided at the points of connection of the filter under test into two parts, one of which contain the generator and the other receiver. Then the impedance of each of these parts shall be measured separately at the points of connection of the filter. VSWR shall be calculated (for each part separately) according to the following formula:

$$VSWR = \frac{1 + |r|}{1 - |r|}$$

where

$$|r| = \frac{Z - R}{Z + R}$$

and

Z = complex value of measured impedance, and

R = rated resistance of the test circuit.

A-2.1.2 *Method II* — The test circuit shall be divided into two parts as in Method I. Then the VSWR shall be measured directly (for example with the help of the slotted line) for each part separately. The maximum error of the VSWR measurement shall be ± 10 percent.

NOTE — When checking the VSWR in the test circuit in which isolation attenuators are used it is allowed to change the generator and receiver for resistors of values equal to their rated resistances.

A-2.2 Attenuation Accuracy Checking — Accuracy checking shall be made with the help of a standard attenuator with the following characteristics:

a) Attenuation of $50 \pm 0{\cdot}5$ dB over the frequency range of interest,

b) Maximum VSWR of 1·2 over the frequency range of interest,

c) Input and output impedances matched to test circuit, and

d) Symmetry coefficient minimum 26 dB (for symmetric test circuits only).

The standard attenuator shall be inserted into the test circuit in place of the filter under test and its insertion loss shall be measured.

Test circuits containing buffer-networks and other arrangements for connecting a current or voltage source shall be checked with these included. The source itself shall be disconnected and terminals for its connection shall be short-circuited.

A-2.3 Frequency Accuracy — Checking shall be made with equipment having accuracies better than 2 percent.

A-2.4 Maximum Measurable Insertion Loss Checking

A-2.4.1 Maximum measurable insertion loss is limited by generator power, receiver sensitivity, leakage of signal from generator to receiver around the filter under test, and by penetration of undesirable external signals.

A-2.4.2 The test circuit shall be set up as shown in Fig. 4B or 5B except the filter under test shall be replaced by a short-circuit the insertion loss of which shall be measured (an example of this short-circuit is shown in Fig. 7).

A-2.4.3 If receiver voltage is a minimum of 1 dB above the circuit noise level then the maximum measurable insertion loss is limited by leakage of the test signal from the generator to the receiver or by undesirable external signals. Otherwise it is limited by the generator power or receiver sensitivity.

A-2.5 Symmetry Coefficient Checking — The test circuit shall be divided at the point of connection of the tested filter into two parts one of which contains the generator and the other the receiver. Then using the auxiliary generator and auxiliary receiver the voltage U_1 and U_2 shall be measured as shown in Fig. 8.

The symmetry coefficient shall be calculated from the formula:

$$k = 20 \log \frac{U_1}{U_2}$$

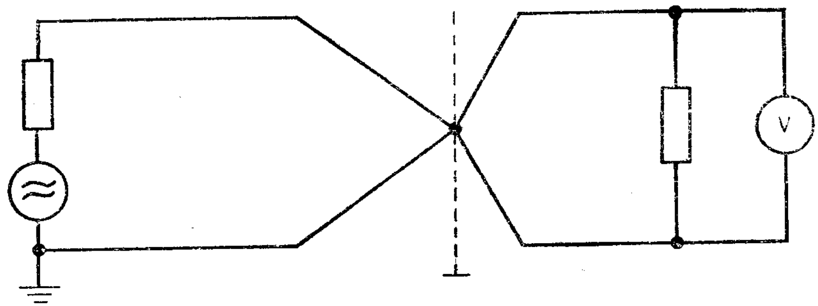
A-3. MODIFICATIONS OF THE BASIC TEST CIRCUIT

A-3.0 Measurements performed in the basic test circuit (Fig. 4B and 5B) need a previously determined reference level (0 dB) in the circuits shown in Fig. 4B and 5B. If the stability of parameters of equipment used is sufficient for maintaining the needed measurement accuracy then the test circuit may be calibrated once in the whole frequency range before the measurements. If stability is insufficient then the test circuit must be calibrated before each measurement separately.

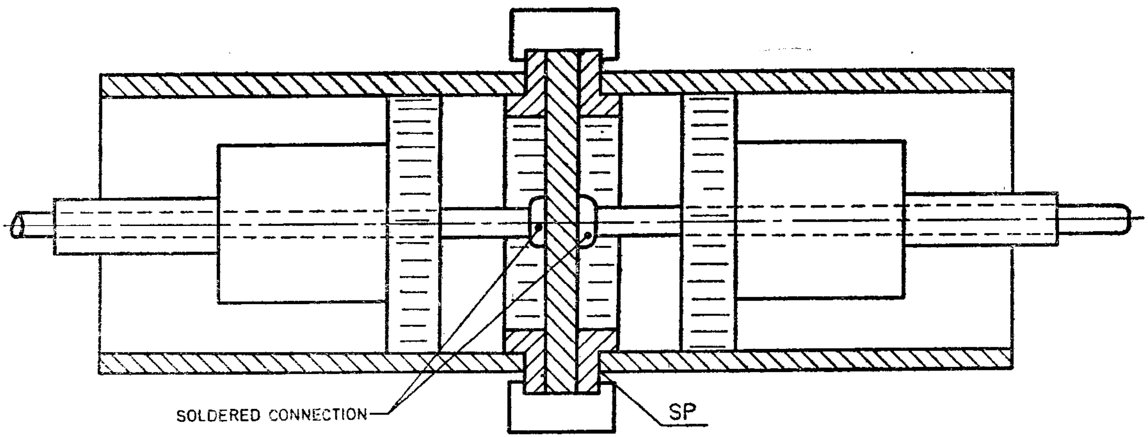
A-3.0.1 Examples of test circuits facilitating such measurements, which are equivalent to basic test circuits are shown in Fig. 9, 10 and 11.

NOTE 1 — These tests are performed on a conducting metallic plate, with all components connected to the plate.

NOTE 2 — The total length of each cable *X* and *Y* on Fig. 9 and 10 between the filter under test, or the calibrated attenuators and the isolation attenuators, shall not be more than 0·05 wavelength at any test frequency. Where difficulties in satisfying this condition arise, for example at frequencies above 50 MHz, the test circuit shown in Fig. 11 may be used in place of that shown in Fig. 9. The two isolating attenuators in the branch containing the calibrated attenuator may be omitted if tests show that, with the coaxial switches in position 1, the VSWR requirement of **A-2.2** is maintained in the lines between generator and receiver. A corresponding circuit may be used in place of Fig. 10.

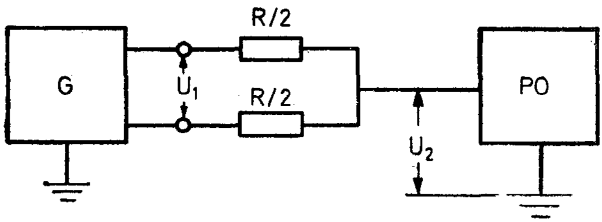


7A Schematic Diagram

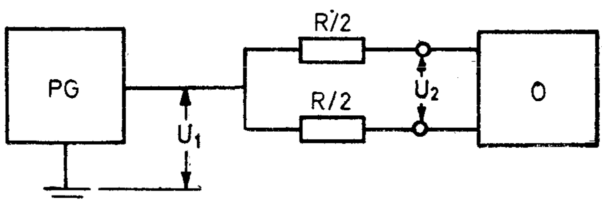


7B The Way of Realization with a Cylindrical Box
SP = Short-circuiting silvered plate

FIG. 7 EXAMPLE OF SHORT-CIRCUIT IN TEST CIRCUIT



8A Checking of Generator



8B Checking of Receiver

G = Generator under test

PO = Auxiliary receiver with asymmetric input

PG = Auxiliary generator with asymmetric output

R = Resistor matched to generator or receiver under test

O = Receiver under test

FIG. 8 CHECKING OF SYMMETRY COEFFICIENT OF TEST CIRCUIT

A-3.0.2 Measurements of loaded filters also shall be performed according to Fig. 9 and 10 but the filter under test shall be replaced by the set of elements shown in Fig. 12 (*see* Appendix B).

A-3.1 General Method of Test with Two Coaxial Switches (*see* **Fig. 9)**

a) *Method I* — The calibrated attenuator is set equal to zero. The input voltage of the receiver shall be maintained for filter-in and filter-out positions of the switches at a constant level (U01 — U02). Insertion loss shall be calculated from the formula given in **A-1.4**, in which the first and last components are zero.

b) *Method II* — The calibrated attenuator is set equal to zero. The output voltage of the generator shall be maintained, for both positions of the switches, at a constant level ($E_{g1}=E_{g2}$). Insertion loss shall be calculated from the formula in **A-1.4** in which the second and last terms are zero.

c) *Method III* — Both generator output level and receiver input level are maintained constant with the filter in and with it replaced by a calibrated attenuator having 1 dB steps. The attenuation is then obtained from the formula in **A-1.4** in which both the first and second terms are zero.

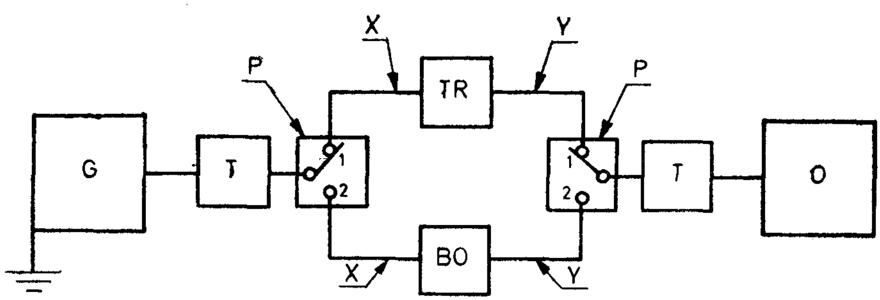
A-3.2 Method of Test with Two Coaxial Switches and Calibrated Attenuator in Series with the Filter Under Test (*see* **Fig. 10**) — The output voltage of the generator and the input voltage of the receiver shall be maintained at a constant level for both positions of the switches. The insertion loss of the filter under test shall be calculated using the formula:

$$A=A_{T1}-A_{T2}$$

where

A_{T1} = insertion loss of the calibrated attenuator for switches in position 1, and

A_{T2} = insertion loss of the calibrated attenuator for switches in position 2.



G = Generator

P = Coaxial switch

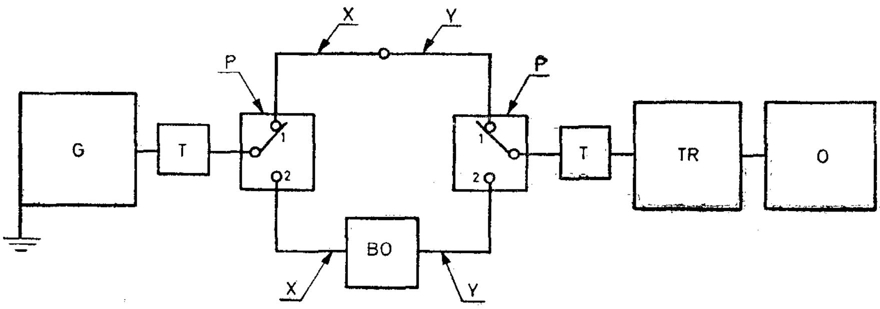
TR = Calibrated attenuator (adjustable)

T = Isolation attenuator 10 dB

O = Receiver

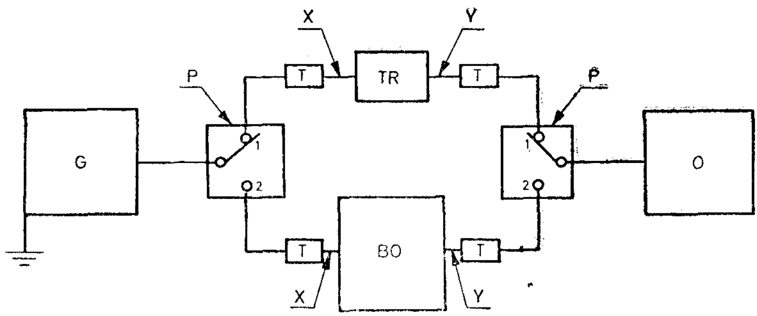
X, Y = Pairs of identical cables

FIG. 9 TEST CIRCUIT WITH TWO COAXIAL SWITCHES AND CALIBRATED ATTENUATOR PARALLEL TO THE FILTER UNDER TEST



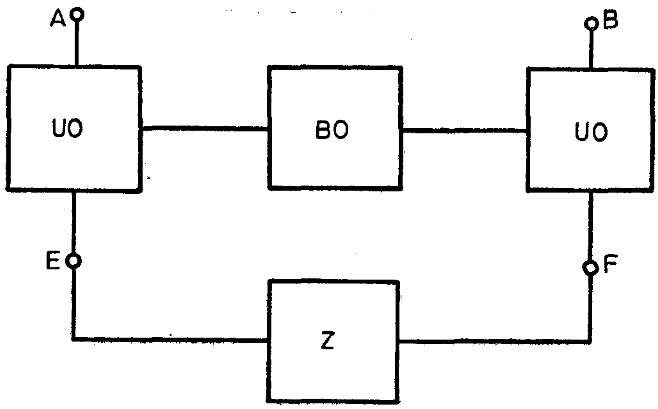
G = Generator		*T* = Isolation attenuator 10 dB	
P = Coaxial switch		*BO* = Filter under test	
O = Receiver		*TR* = Calibrated attenuator	
X, Y = Pairs of identical cables			

FIG. 10 TEST CIRCUIT WITH TWO COAXIAL SWITCHES AND CALIBRATED ATTENUATOR IN SERIES WITH THE FILTER UNDER TEST



G = Generator		*T* = Isolation attenuator 10 dB	
P = Coaxial switch		*BO* = Filter under test	
O = Receiver		*TR* = Calibrated attenuator	
X, Y = Pairs of identical cables			

FIG. 11 TEST CIRCUIT WITH TWO COAXIAL SWITCHES



BO = Filter under test *UO* = Buffer-network

Z = Current or voltage source

FIG. 12 SET OF ELEMENTS REPLACING FILTER UNDER TEST IN FIG. 9, 10 AND 11 WHEN CONDUCTING MEASUREMENTS WITH CURRENT OR VOLTAGE LOAD

APPENDIX B

(*Clauses* A-1.3.3 *and* A-3.0.2)

EXAMPLES OF THE BUFFER-NETWORK

B-1. Circuit diagrams of current source buffer-networks for the frequency range of 0·1 to 30 MHz and 30 to 300 MHz are shown in Fig. 13. Specification of elements of those buffer-networks is given in Table 1.

B-2. The ways of connecting buffer-networks in test circuits are shown in Fig. 14 to 17.

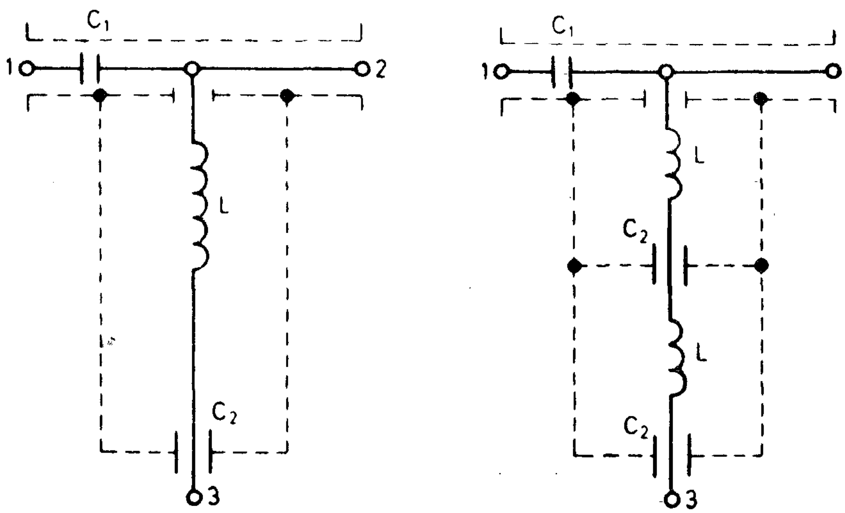
B-3. Before testing the attenuation of the loaded filter, it must be ascertained by a preliminary test made without current or voltage (unloaded filter) that the tests in the frequency range considered are not influenced by the presence of the buffer-network *UO* and of the source *Z*.

TABLE 1 SPECIFICATION OF ELEMENTS OF BUFFER-NETWORKS

(*Clause* B-1)

ELEMENT	FREQUENCY RANGE	
	0·1-30 MHz	30-300 MHz
C_1	Non-inductive capacitor 0·1 μF	Non-inductive capacitor 2 μF
C_2	Feedthrough capacitor 1 μF/100 A	Two feedthrough capacitors 1 μF/100 A
L	Split winding choke	Each choke:
	7×20 turns in five layers	One layer winding 20 turns
	Cotton-covered 5 mm wire	Cotton-covered 4 mm wire
	Open ferrite core:	Open ferrite core:
	Seven 8×220 mm rods of Ni-Zn ferrite with $\mu_1 = 200$	8×42 mm rod of Ni-Zn ferrite with $\mu_1 = 200$
	Choke length 176 mm	Choke length 45 mm
	Choke diameter 75 mm	Choke diameter 15 mm
	L_1 kHz$=$1·2 mH	L_1 kHz$=$2 μH

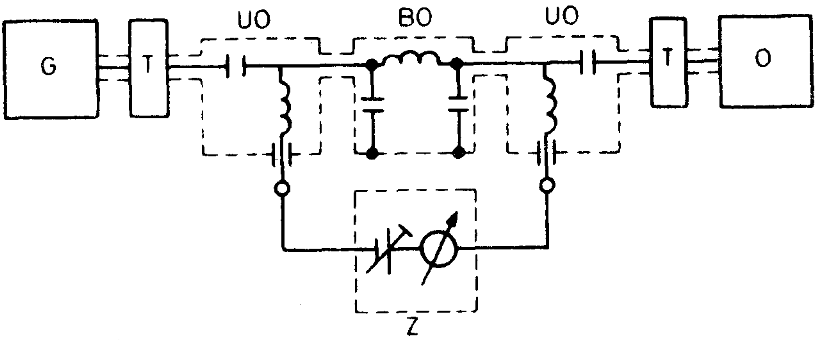
NOTE — Buffer-networks for which parameters are given in this table are designed for 60 A continuous load and 100 A short-time load.



13A For the Frequency Range 0·1 to 30 MHz 13B For the Frequency Range 30 to 300 MHz

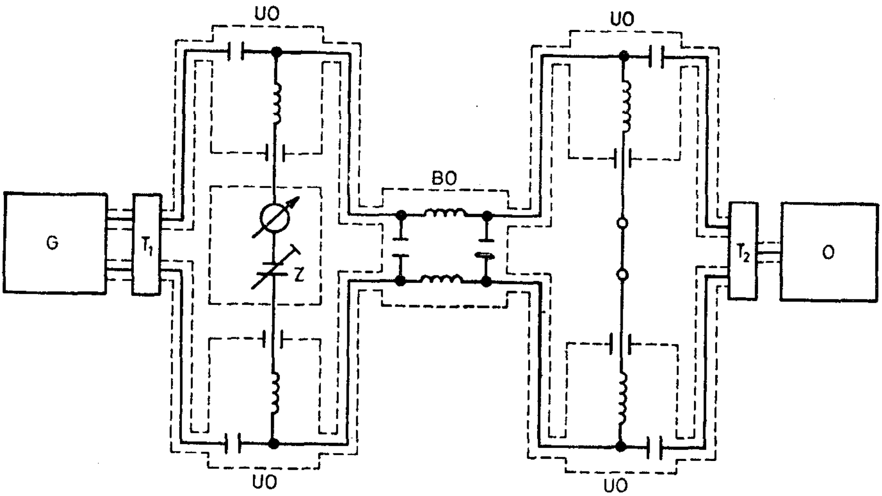
1=To generator or receiver
2=To the filter under test
3=To load current source

FIG. 13 EXAMPLE OF CURRENT SOURCE BUFFER-NETWORKS



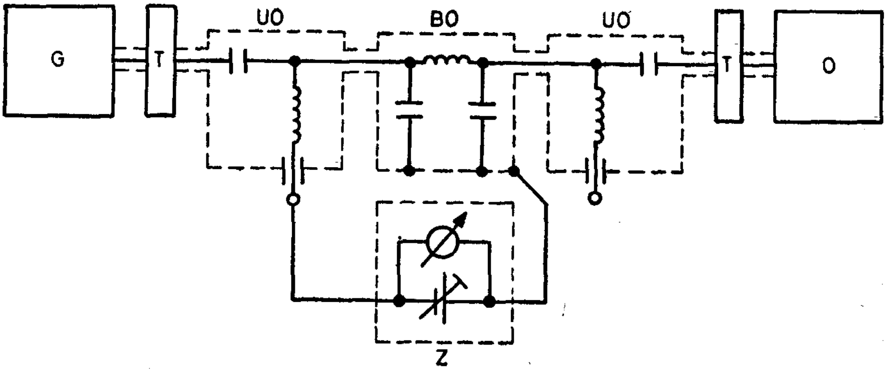
BO = Filter under test
O = Receiver
UO = Buffer-network
G = Generator
T = Isolation attenuator 10 dB
Z = Load current source

FIG. 14 EXAMPLE OF CONNECTING BUFFER-NETWORKS FOR LOAD CURRENT SOURCE IN ASYMMETRIC TEST CIRCUIT



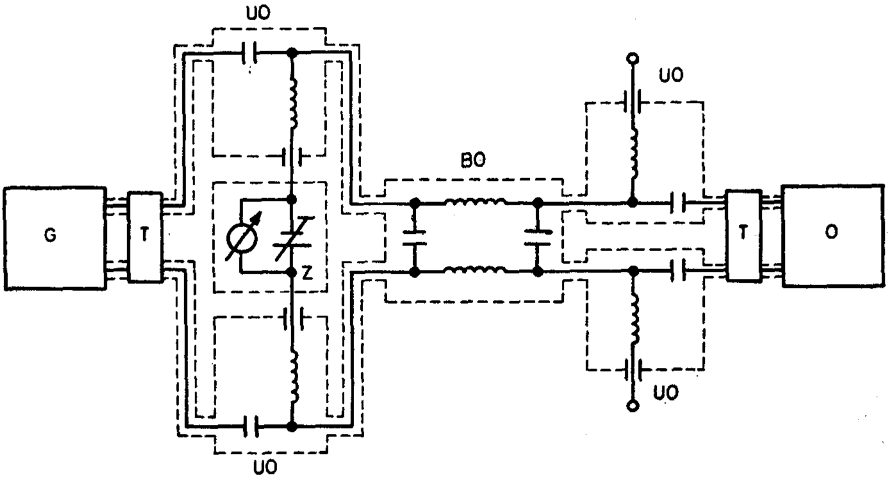
BO = Filter under test
O = Receiver
UO = Buffer-network
G = Generator
T_1/T_2 = Isolation attenuator 10 dB
Z = Load current source (See Note under Fig. 17)

FIG. 15 EXAMPLE OF CONNECTING BUFFER-NETWORKS FOR LOAD CURRENT SOURCE IN SYMMETRICAL TEST CIRCUIT



BO = Filter under test
O = Receiver
UO = Buffer-network
G = Generator
T = Isolation attenuator 10 dB
Z = Load voltage source

FIG. 16 EXAMPLE OF CONNECTING BUFFER-NETWORKS FOR LOAD VOLTAGE SOURCE IN ASYMMETRIC TEST CIRCUIT



BO = Filter under test
O = Receiver
UO = Buffer-network
G = Generator
T = Isolation attenuator 10 dB
Z = Load voltage source

NOTE — In the symmetrical test circuits shown in Fig. 15 and 17, the symmetrical generators and receivers may be replaced with asymmetrical generators and receivers used in conjunction with proper unbalance to balance transformers.

FIG. 17 EXAMPLE OF CONNECTING BUFFER-NETWORKS FOR LOAD VOLTAGE SOURCE IN SYMMETRICAL TEST CIRCUIT